U.S. Department of
Federal Aviation Administration

Aeromedical Research Resume
Research Project Description Subtask for FY00

1. Title:	**2. Sponsoring Organization/Focal Point (FP)**	**3. Originator Name, Organization, Phone:**
Design, Testing, and Evaluation of new ATS Technologies and System Concepts	ARX-1; J. Staples AAM-1; J. Jordan, M.D. ARX-20; S. Pansky (FP) AAR-100; L. Cole (FP)	Carol Manning, Ph.D. Henry Mertens, Ph.D. Roni Prinzo, Ph.D. Scott Mills, Ph.D. Rich Thompson, Ph.D. Julia Pounds, Ph.D. AAM-510 (405) 954-4846 **4. Origination Date:** October 1998
5. Parent RPD Number: 586	**6. Subtask Number:** AM-B-00-HRR-516	**7. Completion Date:** September 2001
8. Parent MNS: ATS Human Factors	**9. RPD Manager Name, Organization, Phone:** David J. Schroeder, Ph.D. AAM-500, FAA Civil Aeromedical Institute (405) 954-6825	

10. Research Objective(s):

The purpose of this research program is to ensure that future ATS systems are designed to accommodate the user. In addition, real-time simulations and longitudinal assessments will be conducted to determine whether the human will be sufficiently accommodated. The program encompasses three areas of research: 1) Conducting simulation studies to assess and compare new capabilities being considered for inclusion in future ATS systems, 2) Developing measurement tools to assess system effectiveness, and 3) Using measurement tools to evaluate the effectiveness of both future ATS systems and the processes used to implement them. This project also supports the development of laboratory facilities that will be used to examine design and development issues associated with proposed ATC systems, and their integration within the National Airspace System (NAS).

11. Technical Summary:

This research will support the development of future ATS systems by providing information about the effects of proposed system functioning on the performance, taskload, and cognitive processing of individual air traffic controllers as well as its effects on system performance measures. The research will also evaluate newly introduced ATS systems and the methods used to introduce them to the workforce, assessing effects on productivity, workload, and organizational climate. However, before simulation testing and system evaluations can be conducted, it is first necessary to develop measures that accurately describe individual and system performance, and to develop simulation facilities.

A set of studies is proposed that will focus on the simulation of future system concepts, development of measures of system effectiveness, and will use the measures developed to evaluate the effectiveness of new systems and the process of implementing those systems. Projects concerning flight strip usage, use of color in STARS, graphical display of both decision support information and factors related to ATC complexity, development of measures of controller taskload, performance, decision making, and situation awareness will be conducted, beginning in FY-99, with some being completed in FY-00. Other studies that measure baseline levels of taskload and performance will also be conducted. In addition, studies will be conducted to evaluate technology and organizational changes implemented in ATS as they relate to productivity, workload, and organizational climate.

12. Resource Requirements:	***FY-99***	***FY-00***

FAA Staff Years:	13.0	13.0

13. Description of Work:

(1) Brief Background

Introduction of new technologies may result in unintended consequences for the ATS system. Problems with automation of the flight deck have already occurred (Billings, 1997). For example, pilots have experienced problems interpreting information presented on displays and maneuvering through systems of menus used to obtain information. Problems have also occurred because aircraft automation does not always display all necessary information to pilots and because pilots may not understand how automation works and so are surprised by actions the automation takes.

Advanced ATC automation has not yet been introduced in the United States and so U.S. controllers have not yet encountered automation problems of the sort that occur in flight deck automation. Nevertheless, knowledge of problems with flight deck automation may reduce the incidence of similar problems with ATC systems. A number of ATS system concepts have been proposed (for example, data link, free flight, conflict probe, electronic flight lists, etc.). To reduce potential automation-related problems, these system concepts should be evaluated thoroughly by using simulation testing before design decisions are finalized. Simulation testing is also useful for comparing alternate versions of displays to determine if any have negative effects on controller workload and performance. It is important in these simulation tests to measure not only easily quantifiable variables such as numbers of aircraft, but also other variables that may be harder to measure, such as complexity, controllers' understanding of the situation, and other kinds of cognitive processing that occur in air traffic control.

Simulation Testing

The first type of research that will be conducted in this program involves simulation testing of new ATS system concepts. Simulation testing of several new system concepts has been conducted by the Human Resources Research Division. For example, a project completed in FY-98 compared the current procedure for using flight strips with an experimental procedure that allowed reduced flight strip marking and posting. A second project examined the effects of CPDLC. Yet another, to be completed in FY-99, provides recommendations for color combinations when coding own aircraft vs other/uncontrolled aircraft to optimize legibility. Finally, a project that will identify methods for graphically representing information related to complexity of air traffic situations is ongoing.

System Effectiveness

The second type of research will develop measures that can be used to compare alternative versions of proposed systems and evaluate the effectiveness of new systems when they are introduced in the field. Several performance and taskload measures have been developed for previous projects, including: measures of cognitive processing, controller performance, workload, efficiency, air/ground communications, and situation awareness. Some of these are subjective, requiring subject matter experts to observe study participants run simulated scenarios and evaluate the performance of the participants, while other measures are based on participants' opinions about experimental procedures or display/system designs. Still others are obtained from actions made by the participant at the time the scenario is running. A project that will be conducted as part of this research program involves the development and validation of measures of air traffic controller decision making. These measures, when completed, will be applied to the assessment of new ATS system concepts. A set of measures derived from objective ATC data has also been developed. These measures, called Performance and Objective Workload Evaluation Research (POWER), are computed from available System Analysis Recording (SAR) data. The output of POWER is a set of numerical measures that may be related to controller taskload as well as both controller and system performance. A study to validate the measures and assess their utility for measuring ATCS taskload and performance will be conducted. When properties and limitations of the measures are understood, they will be applied to the calculation of baseline measures for the current NAS. Another set of measures is being developed to assess the effects of technology implementation and change on organizational perceptions and performance.

Evaluation of New ATS Concepts

The third type of research to be conducted in this program involves utilizing the measures of system and individual performance and effectiveness (as described earlier) to evaluate new ATS system concepts. Besides evaluating human-machine interactions associated with future equipment evolutions, another type of evaluation examining the organizational effects of new systems is planned. Such evaluations, which begin before new equipment is installed, can identify potential problems with workforce acceptance of new systems before implementation occurs and identify problems with system implementation and transition training so they can be avoided in the future. It is expected that the methodologies developed during such projects will be used to evaluate potential effectiveness of new technology implementation. Other, more traditional, organizational assessments will be conducted to generate a longitudinal database for evaluating efforts at enhancing job satisfaction and the overall organizational climate for ATS personnel. Outcomes will also identify progress toward achieving Model Work Environment goals.

(2) Statement of Work Subtasks:

Hypothesis: Potential problems associated with the effects of proposed ATS system changes on individual controller and system performance can be identified through real-time simulation.

Hypothesis: Measures of En Route controller performance, taskload, sector complexity, and decision making can be developed and applied to the evaluation of future ATC systems designs and concepts.

Hypothesis: Measures of technology changes and organizational effectiveness will provide a sufficiently sensitive technique for identifying potential problems associated with implementation of proposed ATC system changes.

The following subtasks will be undertaken in FY-00:

Task 1: Flight Strip Studies.

Studies will be conducted to identify functions of flight strips at URET CCLD facilities so that functional replacements can be included in later versions of URET CCLD software. Alternative procedures for using flight progress strips and alternative designs for electronic flight data displays will be tested. (The latter study depends on completion of the ATCARS simulator.)

Task 2: Operational Pilot/Controller Communication and Evaluation of ADS-B and CDTI.

As part of the FAA's Safe Flight 21 program, an operational evaluation of Automatic Dependent Surveillance Broadcast and Cockpit Display of Traffic Information will be conducted in July, 1999. In support of this effort, voice and radar data recordings will be analyzed to evaluate pilot/controller human factors effects. (Completion of this project depends on the demonstration taking place and acquisition of required data.)

Task 3: Color coding in STARS and other future ATS displays.

While color-coding may enhance performance in some applications, improper use of color-coding can impair performance. If possible, certain applications of color to the STARS environment will be tested, including displaying "owned" and "other/uncontrolled" aircraft using different colors for enhancing identification of classes of aircraft and effects of color coding on conflict monitoring. It has not yet been possible to perform these last proposed research studies on the effects of color coding on conflict monitoring between the controller's "own" aircraft and other aircraft because an appropriate simulation facility has not been identified. ATC simulation facilities under development at the W.J. Hughes Technical Center, CAMI, and the FAA Academy may offer an appropriate high fidelity ATC simulation for this research in the near future. However, initiation of the proposed study will be delayed until an appropriate simulation facility has been identified. Other studies will be conducted to examine effects of noncolor legibility factors, which may be implemented alone on how they may interact with color.

Task 4: Controller decision making.

Controller decision making plays a critical role in ensuring aircraft separation in the current system.

Baseline measures of decision making are needed to develop improved decision aids and assess the effects of automated system concepts. Measures of controller decision making will be developed and evaluated.

Task 5: Plan Generation and Alternative Interface Design in ATC.

The use of planning and strategy by air traffic controllers, in both conventional and free flight simulated environments, will be examined. Alternative user interface tools designed to facilitate such planning will be investigated in a simulated ATC environment.

Task 6: Identification and display of ATC complexity factors.

This collaborative study with the WJH FAA Technical Center Human Factors Laboratory developed graphic displays for factors related to ATC complexity. Simulation studies with ATCSs will be conducted to assess the effectiveness of the proposed display designs.

Task 7: SATORI.

The development and validation of TRACON SATORI will be completed and the system will be used to conduct a research study. (The development and validation effort, along with the study, will depend on contractor completion of the software.) En route SATORI software will be re-written to interpret revised SAR and other system files used with DSR. This will allow transitioning SATORI to the DSR environment.

Task 8: POWER taskload and performance baseline assessments.

Objective measures of controller and system performance are needed to assess the effects of procedural and technological changes. A set of numerical measures based on available SAR data has been developed to assess controller taskload and controller and system performance. A study is being conducted to validate the measures, assess their psychometric properties, and evaluate their utility for measuring taskload and performance. The resulting measures will be used to compute baseline levels of taskload and performance at en route facilities. Knowledge of DSR file structures obtained when DSR SATORI is developed will contribute to the development of an alternative version of POWER that can use DSR files. Data for facilities receiving DSR will be collected and analyzed to compare taskload and performance before and after DSR implementation. Multiple assessments following DSR implementation will be used to assess short- and long-term effects.

Task 9: Effects of technology and organizational transitions on ATS workforce.

Research to identify issues related to organizational and technological changes in the ATS environment will continue. This research will focus on identifying management practices that can be used to enhance the success of technological and organizational transitions. In addition, research will develop measures that identify situations where member support for the change is at risk. Data will be collected from personnel at relevant facilities during organizational and technological changes that are made in the course of this research. Longitudinal assessments of the ATS organizational climate and culture will be conducted to assess progress toward the development of a model work environment and improvement of the overall quality of employees' work life.

14. Intended End Products/Deliverables

Products:

Technical reports identifying the effects of proposed procedural and equipment changes (for example, reduced strip marking and posting, data link, use of color for ATS displays, etc.) that can contribute to management decision making:

- Guidelines for use of color in new system designs
- Identification of potential human factors problems associated with new system concepts before system design is finalized
- Identification of potential problems with workforce acceptance of new systems before implementation occurs

- Development of methods for assessing system effectiveness
- Guidelines for enhancing employee acceptance of new systems
- Comparison of baseline taskload and performance measures with corresponding measures obtained from new systems
- Recommendations for methods of replacing paper flight progress strips.

15. Schedules/Milestones

Task 1: Flight Strip Studies.	
Flight strip usage study	
1.1a Design flight strip usage study	FY00 Q1
1.2a Collect data for flight strip usage study	FY00 Q2
1.3a Analyze data for flight strip usage study	FY00 Q3
1.4a Complete draft report for flight strip usage study	FY00 Q4
Sequential coordination (OU cooperative agreement)	
1.1b Study to describe position relief briefings	FY00 Q2
1.2b Study to assess effects of strip procedures on position relief briefings	FY01 Q2
Electronic flight data displays (Depends on completion of ATCARS simulator)	
1.1c Design specs for contract to assist with completion of ATCARS simulator	FY99 Q4
1.2c Contractor completes pieces of ATCARS software	FY00 Q2
1.3c Integrate contractor-developed software with FAA-developed software	FY00 Q3
1.4c Design study comparing alternative electronic flight data displays	FY00 Q4
1.5c Collect data for electronic flight data study	FY01 Q1
1.6c Analyze data for electronic flight data study	FY01 Q2
1.7c Complete draft report for electronic flight data study	FY01 Q3
Task 2: Operational Pilot/Controller Communication and Evaluation of ADS-B and CDTI.	
2.1 Demonstration occurs	FY99 Q4
2.2 Transcribe voice data	FY99 Q4
2.3 Analyze voice data	FY00 Q1
2.4 Complete draft report of voice data analysis	FY00 Q1
2.5 Process DART data	FY99 Q4
2.6 Analyze SAR data	FY99 Q4
2.7 Complete draft report of SAR data analysis	FY00 Q1
2.8 Complete draft technical report for datalink simulation study that was completed in FY99	FY00 Q1
Task 3: Color coding in STARS and other future ATS displays.	
Selection test for AFSS color weather radar users	
3.1a Collect additional data for practical color test for AFSS	FY99 Q4
3.2a Analysis and report	FY00 Q1
Aircraft ownership study (Depends on finding appropriate simulation capability)	To be determined
3.1b Collect data for study of color for aircraft ownership	
3.2b Analyze data for aircraft ownership study	
3.3b Complete draft report for aircraft ownership study	
Alerting study	
3.1c Design study using color as alert	FY00 Q1
3.2c Collect data for study using color as alert	FY00 Q2

3.3c Analyze data for study using color as alert 3.4c Complete draft report for study using color as alert	FY00 Q3 FY00 Q4
Task 4: Controller decision making. (KSU Cooperative Agreement) 4.1 Design methodology for ATC DM measures study 4.2 Conduct analyses for ATC DM measures study 4.3 Brief results for ATC DM measures study 4.4 Complete draft report for ATC DM measures study **Task 5: Plan Generation and Alternative Interface Design in ATC.** (OU Cooperative Agreement) 5.1 Conduct initial study of ATC strategic planning 5.2 Complete draft report describing initial study 5.3 Design simulation for ATC strategic planning aid 5.4 Collect data using ATC strategic planning aid 5.5 Complete draft report describing planning aid study **Task 6: Identification and display of ATC complexity factors.** (Collaborative project with WJHTC HF Lab) 6.1 Develop displays of ATC complexity factors 6.2 Complete draft report describing displays 6.3 Design simulation studies to assess displays 6.4 Collect data for display study 6.5 Analyze data for display study 6.6 Complete draft report for display study **Task 7: SATORI.** <u>TRACON SATORI (Contractor developed)</u> 7.1a Complete system validation (Depends on contractor progress) <u>DSR SATORI</u> 7.1b Collect, data, analyze format, develop data extraction routines 7.2b Design and implement interface 7.3b Conduct initial validation, develop user guide 7.4b Complete final validation, finalize user guide 7.5b Demonstrate DSR SATORI **Task 8: POWER taskload and performance baseline assessments.** <u>POWER validation study</u> 8.1a Design study to validate POWER measures 8.2a Collect data for POWER validation study 8.3a Analyze data for POWER validation study 8.4a Complete draft report for POWER validation study <u>Baseline study</u> 8.1b Obtain SAR data from selected en route facilities to be used for baseline analysis 8.2b Process baseline SAR data 8.3b Analyze baseline SAR data 8.4b Complete report describing baseline data analysis	 FY99 Q1 Completed FY99 Q3 Completed FY99 Q4 Completed FY99 Q4 FY99 Q2 Completed FY99 Q3 Completed FY00 Q2 Completed FY00 Q3 FY00 Q4 FY99 Q1 Completed FY99 Q3 Completed FY99 Q4 FY00 Q2 FY00 Q3 FY00 Q4 FY00 Q1 FY00 Q3 FY00 Q4 FY01 Q1 FY01 Q2 FY01 Q2 FY99 Q2 Completed FY99 Q4 FY00 Q1 FY00 Q2 FY00 Q1 FY00 Q2 FY00 Q3 FY00 Q4

<u>DSR-baseline comparison (Depends on completion of DSR SATORI)</u> 8.1c Collect early post-DSR SAR data for comparison with baseline 8.2c Process early post-DSR SAR data	 FY00 Q4 FY01 Q2

8.3c Analyze early post-DSR SAR data	FY01 Q3
8.4c Complete report describing comparison of baseline and post-DSR data	FY01 Q4
Task 9: Effects of technology and organizational transitions on ATS workforce.	
Technology Change Best Practices	
9.1a Data analysis	FY00 Q2
9.2a Submit draft report	FY00 Q3
Longitudinal ATS organizational climate assessment	
9.1b Develop survey	FY00 Q4
9.2b Administer survey	FY01 Q2
9.3b Data reduction and analysis	FY01 Q3
9.4b Prepare FAA and Line of Business reports	FY01 Q3
9.5b ATS facility summary reports	FY01 Q4

16. Procurement Strategy /Acquisition Approach/Technology Transfer:
Research on this project will be conducted by in-house staff with varying backgrounds in human factors, experimental design, vision, software development, decision theory, organizational development, and industrial psychology. Several contracts and grants/cooperative agreements with highly qualified researchers from organizations such as the FAA William J. Hughes Technical Center, the University of Oklahoma Psychology and Computer Science Departments, the Kansas State University Department of Psychology, and other academic institutions will be used to expand our ability to address certain issues. Technology transfer will be available through the scientific media and existing FAA structures. It is anticipated that the acquisition of specialized hardware/software will be required to enhance and upgrade our capability to develop ATC simulations for assessing the effects of color-coding and other future display characteristics and prototypes on controller performance.(approx. $350K)

17. Justification/History:
The research program described here provides direct support for several research categories included in the ATS Human Factors Research Project Description for FY-00. These are ATC Information Display and Interface Design, Decision Support Systems and Collaborative Decision-Making, Airspace Design and Procedures Human Factors, and General Human Factors Research. The program also relates to other FAA planning documents, such as the FAA Strategic Plan (under the Human Factors goals for safety and system capacity), the NAS ATM R&D Advisory Committee, which recommended looking at the effects of Free flight on controller performance. The program also supports the ATS Operations Concept for 2005 NAS, as well as goals in the En route/Oceanic Mission Needs Statement. This research also supports the enabling activities described in 1997-99 ATS Business Plan. These research program activities are designed to respond to requirements and information needs identified in the NAS Architecture Version 4.0. This includes chapters: 19.3 NAS Information Architecture and Services for Collaboration and Information Sharing – Human Factors; 20.3 Traffic Flow Management – Human Factors; 21.3 En Route – Human Factors; 23.3 – Terminal – Human Factors; and various NAS-Architecture Supporting Elements (Chapter 8 Human Factors Activities – life cycle costs, benefits, and tradeoffs, human performance metrics and baselines, consistent computer-human interface prototypes, human-in-the-loop simulations, and task analysis and workload measurement).

***18. Issues**:*
Conducting this research will require air traffic control specialists to serve as participants in research studies. Simulation laboratories at CAMI, the FAA WJH Technical Center's Human Factors Laboratory, the FAA Academy's Radar Training Facility, or FAA field facilities will be used. A description of research protocols and subject consent forms will be reviewed by the FAA Institutional Review Board. When appropriate, coordination for access to controllers to participate in research studies will occur through ARX-100, ATO-400, Labor Relations, and NATCA. It is also necessary to obtain accurate and up-to-date system/service descriptions and obtain timely information about system changes. Coordination with management at various field facilities will be required to support the collection of SAR data and the collection of other relevant data required to evaluate new systems. Access to this type of information will be arranged through ARX-100 and/or ATO-400. It will be necessary to obtain additional equipment and specialized software to complete simulation facilities.

19. Transition Strategy:

This project will produce methods for evaluating proposed future ATS system concepts. Simulation studies will be conducted to compare and assess these system concepts. Other studies will assess effects on performance, productivity, and organizational climate resulting from the introduction of new air traffic control systems. Based on laboratory studies of alternative design configurations, recommendations will be made for future versions of automation that should increase productivity and reduce errors. Results of research conducted as part of this project will be in the form of recommendations for methods to display information, revise procedures, or conduct system implementations that should reduce the likelihood of negative consequences associated with technology change. The recommendations will be documented in technical reports, and will be briefed to FAA ATC managers, program managers, and members of controller teams. Discussions will be held to determine how the results might be implemented.

20. Impact of Funding Deferral:

Deferral of funding for simulation studies will result in failure to identify human factors problems associated with future ATS system concepts in a timely manner. Such a lack of identification could lead to committing to a flawed system design that would have to be changed late in the development process, resulting in delays and excessive costs. Deferral of funding for development of individual and system measures of performance, taskload, decision-making, etc., will result in failing to evaluate the effectiveness of new systems after they are implemented. Not conducting evaluations of the effectiveness of new systems will result in failing to incorporate lessons learned into plans for implementation for future systems and may lead to the same mistakes being made again.

21. R&D Teaming Arrangements:

This program of research is related to other research being conducted at CAMI. For example, knowledge gained from the development of SATORI contributed to the methods that the ATCARS simulator uses to obtain, display, and record simulation data, and to the development of POWER software. Knowledge gained from these projects is being incorporated into a redesign of the Operational Error/Deviation reporting form. Measures developed as part of this research program will be used to evaluate the effects of environmental factors on controller performance. The development of the performance measures used in these studies will be linked to the development of criterion performance measures required for validation of new selection procedures.

CAMI Principal Investigators involved in this research program also collaborate on external projects. For example, researchers are collaborating with FAA WJHTC, NASA, and MITRE researchers on a project to develop dynamic density measures for ATM systems. A collaborative project with members of the Human Factors Laboratory at the FAA WJHTC has been underway for over a year. Tasks involving color coding in future ATC displays will involve collaboration with Volpe National Transportation Systems Center and the FAATC. CAMI Principal Investigators also participate on aviation committees, for example, the SAE G-10 Free Flight and Data Link subcommittees. CAMI researchers also participate in Technical Interchange Meetings with university scientists and researchers in ATC from the United States, Eurocontrol, and other European governments. CAMI also teams with researchers from University of Oklahoma, Kansas State University, and the University of Illinois to accomplish research relevant to air traffic concerns.

22. Special Facility Requirements:

Some studies will be conducted in laboratory facilities available at CAMI. These include the Air Traffic Control Advanced Research Simulator (ATCARS), which simulates ATS future system concepts; the Color Vision laboratory, which includes equipment for measuring color vision deficiencies as well as operational ATS equipment requiring the use of color; the Systematic Air Traffic Operations Research Initiative (SATORI) system, which allows re-creation of air traffic situations based on an integration of files produced by DART and NTAP with digitized pilot/ controller communications. Some studies have also been conducted at the FAA Academy's Radar Training Facility (RTF). To generalize the results of any of these studies to the operational environment, it will be necessary to replicate or expand some of the experiments using operationally current air traffic controllers running simulated scenarios in training labs located at FAA ATC field facilities. Data for selected studies will be collected via specialized questionnaire probes directly from controllers at field facilities.

23. Approvals (Signature Authority): ***Project Revalidation***	***Performing Organization***

<table>
<tr><td>Jon L. Jordan, M.D.
Federal Air Surgeon (AAM-1)</td><td>Date</td><td></td></tr>
<tr><td>John Staples
Director, Plans and Performance
Program (ARX-1)</td><td>Date</td><td>William E. Collins, Ph.D.
Director, FAA Civil Aeromedical
Institute, AAM-3

Date</td></tr>
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